



## **POLYMER COMPOSITE BASEBALL BAT ENDCAP**

### **FIELD OF THE INVENTION**

[001] The present invention relates to baseball bats and more particularly to tubular baseball bats, whose performance, as defined by hitting distance, is controlled by performance standards established by regulatory bodies, and to baseball bats where player bat control when hitting is important, and more specifically to an end cap, or plug, for such baseball bats.

### **BACKGROUND OF THE INVENTION AND PRIOR ART**

[002] Baseball and softball bats, hereinafter referred to simply as “baseball bats” or “bats”, are today typically made solely from aluminum alloys, aluminum alloys in combination with composite materials (hybrid bats), or solely from composite materials (with the exception of solid wooden bats for the Major Leagues). Such bats are tubular (hollow inside) in construction in order to meet weight requirements, and have a cylindrical handle portion for gripping, a cylindrical barrel portion for striking, a tapered mid-section connecting the handle and barrel portions, a knob at the handle end, and an end cap, or plug at the barrel end, hereinafter referred to simply as an “endcap”.

[003] All tubular bats require a knob at the handle end and an endcap at the barrel end to close off the respective bat ends. In particular, regulations require the barrel end of tubular bats to be sealed with an endcap in such a manner that the player cannot alter the interior of the barrel or add foreign material to the interior of the barrel. In addition, the prior art endcaps provide structural integrity at the barrel end such that the barrel end does not permanently deform inward with ball impacts. Prior art endcaps also add weight at the barrel end which can increase bat momentum during the swing phase of the bat. The added weight of the prior art endcaps, along with the weight of adhesives employed, typically polyurethane, can be in excess of two ounces.

[004] US Patent 5,954,602 to Eggiman discloses a complex and multi-component polymer (i.e. plastic) endcap plus added polyurethane adhesive with objectives including adding weight to the barrel end.

[005] US Patent 5,785,614 to MacKay discloses a complex polymer (i.e. plastic) endcap with objectives including concentrating the weight load of the bat at the barrel outer end.

[006] US Patent 4,744,136 to Foreman discloses a method for manufacturing an end weighted baseball bat including a heavy hard rubber endcap.

[007] US Patent 3,861,682 to Fujii discloses a tubular metal bat with a sound arresting ring made of rubber or plastic with a plastic endcap.

[008] US Patent 3,811,596 to Wilson discloses a complex and multi-component endcap with inner component of styrene, brass, steel, or aluminum and outer component of polyvinyl chloride, polyethylene, or rubber.

[009] US Patent 3,116,926 to Owen discloses a weighted baseball bat with means of selectively adding weight to the barrel end.

[0010] US Patent 1,499,128 to Shroyer discloses an all metal baseball bat including a relatively heavy metal endcap and the ability to add variable weight to the bat barrel end.

[0011] Numerous other US patents disclose specific innovative features of tubular baseball bats generally relating to improved bat performance. Numerous patents for such baseball bats mention an endcap and when the endcap material is mentioned, it is generally made of plastic, polyurethane, or rubber. Such US patents include patent nos. 1,611,858; 3,727,295; 3,801,098; 3,479,030; 3,830,476; 3,841,130; 3,876,204; 3,963,239; 4,056,267; 4,600,193; 4,744,136; 4,951,948; 5,219,164.

[0012] Generally prior art tubular baseball bat endcaps are made of metal, rubber, plastic, or polyurethane material, and generally include complex features such as ribs,

spokes, grooves, etc. that add weight to the end cap. Further, most prior art objectives include increasing weight at the bat's barrel end to increase bat performance.

[0013] When aluminum alloys initially replaced wooden bats in most bat categories, the original aluminum bats were formed as single members, that is, they were made in a unitary manner as a single-walled aluminum tube for the handle, taper, and barrel portions. Such bats are often called single-wall aluminum bats and were known to improve performance relative to wooden bats as defined by increased hit distance. More recently (in the mid 1990's), improvements in bat design largely concentrated on further improving bat performance. This was accomplished primarily by thinning the barrel or hitting portion of the bat and adding inner or internal, and or outer or external, secondary members extending along the entire barrel length. These members are often referred to respectively as inserts or sleeves while the main member is often referred to as a body, shell or frame in the prior art. Such bats are often called double-wall bats or multi-walled bats in the case of more than two walls.

[0014] The prior art of such single walled, double walled and multi-walled tubular bats generally refer to improved performance or hit distance resulting from trampoline effect, spring, compliance, rebound, flexibility, etc. resulting from the multi-wall two or more member construction along the entire barrel length allowing the barrel portion of the bat to deflect or flex more upon ball impact which propels the ball faster and further than earlier bats. The scientific principle governing improved bat performance is bending theory. When a ball impacts a bat it has kinetic energy that must be absorbed by the bat in order to stop the ball. The bat stores this energy by flexing. After the ball is stopped, the bat returns the energy it stored by rebounding and sending the ball back towards where it came from. The more the bat barrel or striking portion deforms upon ball impact without failing (i.e. denting or breaking), the lower the energy loss in the ball, and the greater the energy return to the ball from the bat as the tubular bat barrel portion impacted returns to its original shape. To allow the bat barrel portion to deform requires lowering the radial stiffness of the barrel portion. The prior art double walled and multi-walled tubular bats accomplish this by thinning the main member barrel portion and adding thin secondary member insert(s) and/or sleeve(s) which are not joined to the main member,

extend full length of the barrel portion, and result in lowered constant stiffness along the barrel portion.

[0015] While the prior art single member, and more particularly, double-walled and multi-walled tubular bats have demonstrated improved performance, various regulatory bodies have raised safety concerns regarding improved performance bats. Consequently, some of the regulatory bodies have established lowered maximum performance standards for various categories of baseball bats under their jurisdiction. As a result, manufacturers of baseball bats are required to pass various controlled laboratory tests, such as, bbf (batted ball performance), bbs (batted ball speed), etc. All such tests are influenced by the weight distribution along the length of the bat. Specifically, actual bat performance and bat performance tests both show increased bat performance with added weight at the barrel end such as added by prior art barrel endcaps.

[0016] It is well known that power hitters, or homerun baseball hitters, are able to hit the ball further with bats that have extra weight at the barrel end (i.e. end-loaded bats), wherein the extra weight could be added by the prior art endcaps. Such players are generally described as big and strong and thus are able to obtain maximum bat-force  $F$ ,  $F$  being equal to  $MV^2$ , where  $M$  is the bat mass and  $V$  is the bat swing-speed. Prior thinking has assumed that a heavier endcap is preferable for increasing this kind of bat performance. Conversely, it is well known that singles hitters are able to perform better (i.e. improve their batting average) with lighter bats, particularly with bats that do not have extra weight at the barrel. Such players are generally described as smaller, and not as strong as homerun hitters, and thus are able to better control lower weight bats, and particularly bats with less end load. Such hitters greatly outnumber homerun hitters and are more interested in improving their batting average than in hitting homeruns.

[0017] Therefore, what is needed is a light-weight barrel endcap to provide bats of lower weight and more specifically, lower barrel end loaded bats, for players primarily interested in improving their hitting or batting average. Such an end cap should be of simple geometric shape, able to maintain its structural integrity, and serve effectively in closing-off the barrel end of a tubular baseball bat. Furthermore, what is also needed is a relatively simple baseball bat endcap, preferably of unitary construction without complex

features such as ribs, spokes, grooves, etc. which is light weight such that it does not materially increase weight at the barrel end of tubular baseball bats and therefore does not increase bat performance beyond standards of regulatory bodies.

[0018] The invention in its general form will first be described, and then its implementation in terms of specific embodiments will be detailed with reference to the drawings following hereafter. These embodiments are intended to demonstrate the principle of the invention, and the manner of its implementation. The invention in its broadest and more specific forms will then be further described, and defined, in each of the individual claims which conclude this Specification.

### **SUMMARY OF THE INVENTION**

[0019] A main object of the present invention is to change weight distribution along the length of a baseball bat, specifically to move the balance point of the bat closer to the handle, thus lowering the moment of inertia of the bat. The lower weight endcap of the present invention allows lowering the bat performance as may be required by ongoing changes to bat performance standards, increases the control of the bat by the player while swinging and allows greater bat swing-speed.

[0020] A second object of the present invention is to provide a singular component endcap of simple geometric shape, without stiffeners, ribs, rings, etc., and of thin uniform thickness, in order to maintain low weight, the simple geometric shape being for reducing tooling and manufacturing costs.

[0021] A third object of the present invention is to provide an endcap, which is sufficiently strong and stiff to maintain structural integrity, thus preventing permanent deformation of the barrel end from ball impacts while maintaining low weight.

[0022] A fourth object of the present invention is to close off and seal the barrel end of a tubular bat with an endcap without adding substantial weight to the barrel end in a manner that prevents the endcap from becoming loose during repeated bat-ball impacts and also prevents players from removing the endcap to change the barrel interior.

[0023] The objects of the present invention are accomplished by providing a thin endcap, of simple geometric shape and unitary construction, made of a light-weight, stiff and strong polymer composite material. Such endcap is preferably bonded to the barrel end of the tubular baseball bat, as by an adhesive, without the need to add liquid polyurethane to the interior of the bat barrel end.

[0024] More particularly, according to one variant, the invention addresses an endcap which includes a polymeric fiber-supporting matrix and at least two courses of continuous length fibres embedded therein, said continuous length fibres being oriented in at least two directions across the endcap. Preferably said endcap has a transverse stiffness of at least four times, even more preferably 10 times, greater than that of an endcap of the same shape and the same polymeric fiber-supporting matrix but lacking said fibers.

[0025] According to a preferred embodiment, the endcap has a weight of less than 1 oz, more preferably a weight of less than 0.5 oz. Further, the endcap is preferably of singular construction.

[0025] The endcap has a central end-enclosing region and an outer, bat-engaging peripheral region, said central region having a substantially constant thickness. More preferably, said central enclosing region and said outer, bat-engaging peripheral region, have the same substantially constant thickness, preferably less than 0.15 inches, more preferably less than 0.10 inches. According to a further preferred feature of the invention, said polymer composite material comprises a resin matrix for encapsulating reinforcement fibers wherein said resin is selected from the group of resins consisting of epoxy, vinyl, polyester, urethane, nylon, and mixtures thereof and wherein said reinforcement fibers are selected from the group consisting of fiberglass, graphite, carbon, aramid, boron, nylon and mixtures thereof. The reinforcement fibres are preferably selected from the group of fibers consisting of graphite and carbon.

[0026] The endcap may be bonded to the tubular bat barrel end with a thin film adhesive, wherein the thin film adhesive is less than 0.05 inches thick and wherein a

bonding zone is provided that is limited to a width of less than 1 inch of the interior, or exterior or intermediate circumferential barrel walls at the barrel end.

[0027] According to the present invention, employing a light weight polymer composite barrel endcap for tubular baseball bats to change the bat weight distribution along the bat length allows bats to be adjusted to conform the bat performance to rules of regulatory bodies. Further, such lowered weight can be utilized to improve bat control by the player during the swing phase of the bat as well as to increase the bat speed during the swing phase. Further, the endcaps of the present invention when of unitary construction and simple geometry can be manufactured with relatively low tooling and manufacturing costs. The endcaps of the present invention are both stiff and strong enough, while maintaining low weight, to prevent permanent deformation of the bat barrel end which could result from ball impacts at the bat barrel end. Furthermore, the endcaps of the present invention can close-off the bat barrel end by being adhesively bonded to the bat barrel end using thin film adhesives, the thin film adhesives being employed to maintain low weight.

[0028] The foregoing summarizes the principal features of the invention and some of its optional aspects. The invention may be further understood by the description of the preferred embodiments, in conjunction with the drawings, which now follow.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0028] The invention will now be described with reference to the accompanying drawings, in which:

[0029] Fig. 1 shows a schematic exploded perspective of a typical prior art plastic, geometrically complex, multi-component, relatively heavy endcap having a lower base and an upper insert.

[0030] Fig. 2 shows a longitudinal cross-section of a typical single wall tubular baseball bat with the light-weight, geometrically simple, polymer composite endcap 14 of the present invention.

[0031] Fig. 3 shows an enlarged longitudinal cross-section 19 of Fig. 2 through the bat barrel end and the polymer composite endcap 14 of the present invention wherein the endcap 14 is bonded to the inner diameter wall of a tubular bat.

[0032] Fig. 4 shows an enlarged longitudinal cross-section 19 through the bat barrel end and polymer composite endcap 14 of the present invention showing the endcap bonded to the exterior diameter wall of a tubular bat.

[0033] Figs. 5a through 5e show illustrative alternative simple geometric shapes of the polymer composite endcap 14 of the present invention.

[0033] Figs. 6A, 6B and 6C respectively show plan, cross-sectional profile and perspective views of an endcap, with the perspective view showing the directions for two intersecting courses of reinforcing fibers.

[0033] Figure 7 is a perspective view of a two-part mold as positioned before closing over two portions of braided textile for the injection molding of the endcap according to the invention.

[0033] Figure 8 is a sideview of an endcap as in Figure 6B being subject to a stiffness test by application of a weight applied over a plate which bears on the endcap.

## **DETAILED DESCRIPTION OF THE INVENTION**

[0034] A typical prior bat endcap is shown in Fig. 1. Such typical prior art endcaps are made of polymer or metal and are of relatively complex geometry (e.g. ribs 1, lugs 2, grooves 3, etc.). They require expensive tooling, and generally require urethane added to the entire interior 18 of the endcap 14 to aid in fastening the endcap to the barrel end, such urethane increasing the barrel end weight. Typically, such prior bat endcaps of Fig. 1 weigh in excess of 1.5 ounces and the urethane adds an additional 1.5 ounces or more for a total added barrel end weight of at least 3 ounces.

[0035] All tubular baseball bats consist of a barrel or hitting portion 4, a handle or gripping portion 6, with a tapered section 5 joining the barrel portion 4 and gripping portion 6. These parts are shown in Figure 2. Though not shown in Fig. 2, all tubular



metal bats include a traditional knob at the extreme handle end portion 7 which serves to close off the handle end 7 and to prevent the players hands from slipping off the handle portion 6 while hitting.

[0036] Most adult tubular baseball bats have a maximum outside barrel diameter 12 of 2.625 or 2.75 inches. Depending on the taper portion geometry of the mid-section 5 and the total length of the bat, the barrel length 10, as defined by length of constant maximum diameter 12, ranges from 4 to 12 inches. Barrel wall thickness 9 ranges from .100 inches to .220 inches.

[0037] Most youth baseball bats and softball bats have maximum outside barrel diameter 12 of 2 or 2.25 inches. Depending on the taper portion geometry of the mid-section 5, the barrel length 10 ranges from 4 to 16 inches. Barrel wall thickness 9 ranges from .060 to .220 inches.

[0038] A typical polymer composite endcap 14 of the present invention is shown in Fig.2 as being adhesively bonded to a single member, or single wall, tubular baseball bat. The polymer composite endcaps 14 of the present invention have continuous fibers 35A, 35B, preferably of carbon-graphite, embedded in an epoxy polymer matrix. While not shown, the typical polymer composite endcap 14 of the present invention can also be assembled to multi-member or multi-wall tubular baseball bat intermediate walls regardless of whether of not such bats have interior insert and/or external shells, and/or other bat components or members.

[0039] The object of the invention as shown in Fig. 2, is to provide a light weight polymer composite barrel endcap 14 for tubular baseball bats to change the bat weight distribution along the bat length 16 in order to conform the bat performance to rules of regulatory bodies. Further, such lowered weight can be utilized to improve bat control by the player during the swing phase of the bat as well as to increase the bat speed during the swing phase. Further, the endcaps 14 of the present invention are of unitary construction and simple geometry, which means they can be manufactured with relatively low tooling and manufacturing costs. Further, the endcaps 14 of the present invention are both stiff and strong enough, while maintaining low weight, to prevent permanent deformation of

the bat barrel end 17 which could result from ball impacts at the bat barrel end 17. Further, the endcaps 14 of the present invention close-off the bat barrel end 8 by being adhesively bonded to the bat barrel end 17 using thin film adhesives, the thin film adhesives being used to maintain low weight.

[0040] An enlarged cross-section of a single-member tubular baseball bat barrel end portion 19 with a light weight polymer composite endcap 14 of the present invention bonded to the interior barrel wall diameter surface 11 is shown in Fig. 3. The length of the bonding surface 20 is up to but typically less than 1 inch in length. A high strength thin film adhesive such as methacrylate sold by Plexus Corporation as MA300, laid down in a layer preferably less than 0.05 inches more preferably 0.03 thick, is the preferred permanent bonding agent. Such an adhesive typically has a shear strength of 3500 psi, a tensile strength of 3500 psi, and a tensile elongation of 25%. The endcap normally has a diameter of 2.625 or 2.75 inches for adult baseball bats, and 2.25 inches for youth and softball bats.

[0041] Similarly, an enlarged cross-section of a single-member tubular baseball bat barrel end portion 19 with a light weight polymer composite endcap 14 of the present invention bonded to the exterior barrel wall diameter surface 12 is shown in Fig. 4. Though not shown, a lightweight polymer composite endcap 14 of the present invention can be also be joined permanently to one or more internal and/or external and/or interior walls of a multi-member tubular bat.

[0042] The light-weight polymer composite endcap 14 of unitary construction has a wall thickness 15 preferably less than 0.1 inches and is generally of uniform thickness along its cross-section. The cross-sectional shape is simple in geometry as shown in Figures 3, 4, and 5a-5e. Typical shapes while not limited to the shapes shown in Figs. 5a through 5e, may be generally described as straight, dimpled inward, or dimpled outward as shown.

[0043] Figures 6A-6C show the actual endcap of the invention in a preferred, partially inwardly dimpled, variant. The endcap 14 is shown as having a side wall 30 to serve as a bat-engaging peripheral region, an open rim 31, a bent rim 32, an inwardly

dimpled shoulder portion 33 and a relatively planar, end-closing central region 34. In Figure 6C the paths of two exemplary transverse fibers 35A and 35B lying within the surface of the endcap 14 are depicted. Single fibers are shown in this figure for simplification. Such courses of fibers 35A, 35B are oriented in different directions preferably in the case of two courses, as shown in Figure 6C, at substantially right angles to each other. It will be seen that the fibers 35A, 35B preferably span from the open rim 31 on one side, to the open rim 31 on the other side of the endcap 14.

[0044] The fibers 35A, 35B are preferably distributed across the surface of the endcap 14, preferably generally evenly, but may be limited to regions. The fibers 35A, 35B increase the stiffness of the endcap 14 to at least four times over the stiffness of the endcap 14 without the fibers being present, more preferably by at least ten times.

[0045] In Figure 7 a two-part die having a lower die portion 36 and an upper die portion 37 is depicted. These portions 36, 37, are shown separated before the die closes. A shaft 38 connected to a hydraulic actuator (not shown) closes these two parts together. In the lower die portion 36 a recess is formed having a peripheral planar portion 38 and a central depressed region 39 that corresponds to the shape of an endcap 14 to be molded within such central depressed region 39.

[0046] The die is fed with thermosetting polymer material through a sprue opening 40 connected through piping 41 to an injector 42 that draws polymer molding liquid from a reservoir 43. Placed within the peripheral planar portion 38 and central depressed region 39 is a swatch of braided textile 44 containing the fibers 35A, 35B of the preferred type, preferably in tows of a ribbon-like format. Use of the ribbon-like format for the fibers provides a fabric which more readily conforms to the shape of the mold as ribbons will shift position more readily to achieve conformity to the die cavity.

[0047] The first cloth 44 is laid over the central depressed region 39 so that, upon closing of the die parts, it will lie within the thickness of the wall of the endcap 14 to be molded. Part of the cloth 44 extends into the peripheral planar portion 38. An optional second piece of braided fabric 45 is depicted suspended above the lower piece 44 for clarity of understanding. In fact, the second piece 45 is placed directly over the lower

piece 44 before the die is closed, preferably lying with its fibers oriented at differing angles, ideally at 45 degrees, to the fibers in the first layer 44. Upon the closing of the die parts 36, 37 the fabric resides in a gap formed above the planar portion 38 and central depressed region 39 and polymer molding material is injected to fill this gap. Alternately, polymer may be provided manually. The wall 46 represents the height of this gap (exaggerated in the Figure for clarity).

**[0048]** Formed on the underside of the upper die part 37 is a cylindrical form 47 that fits within the central depressed region 39. The gap (not shown) between the cylindrical form 47 and the central depressed region 39 contains the transverse fibers provided by the cloth 44, 45 and eventually defines the thickness of the side wall 30 and central planar portion 38 of the endcap 14. Once the molding process is completed, the material overlying the planar portion is removed from the endcap 14 as flashing. This completes the formation of the endcap 14.

**[0049]** While the use of two fabric portions 44, 45 is depicted in Figure 7, it is sufficient for a single piece of fabric to be employed. To provide stiffness, it is preferable that at least two intersecting courses of fibers 35A, 35B be provided in the composite material of the endcap 14. Further, it is preferable that the fibers 35A, 35B are continuous and extend to the outside rim 31 on both sides.

**[0050]** In Figure 8 a procedure is depicted by which the relative stiffness of an endcap 14 of the invention may be determined. The endcap 14 is positioned on its side wall 30 over a rigid supporting surface 47. A contact plate 48 is placed against the top portion of the side wall 30, the contact plate being held in a horizontal orientation (by mechanisms not shown). The height of the upper 49A (or lower) surface of the plate is then established. When a weight 50 is applied to the plate 48, the height of the displaced surface 49 B. is again measured. The difference is the dimension "T."

**[0051]** It has been determined that the dimension "T" is at least four times smaller with fibers according to the invention present in the endcap 14 than when a nearly identical endcap is made without such fibers being present. Measured values for "T" for various weights have been observed as follows:

Load	T (with fibres)	T (no fibres)
10 psi	.02"	.11"
20 psi	.05"	.29"
30 psi	.07"	.46"
40 psi	.10"	fractured

**[0052]** In this manner, the stiffness of an endcap according to the invention may be demonstrated. By reason of such stiffness, it becomes possible to produce an endcap 14 of reduced weight with sufficient strength and stiffness.

**[0053]** Prior art plastic endcaps typically weigh in excess of 1.5 ounces for adult baseball bats and 1.2 ounces for other bats while high viscosity urethane added to, and covering the entire internal cross-sectional end 18 adds an additional 1.5 to 2 ounces for a total weight generally in excess of 3 ounces added to the barrel end 19. Metal endcaps add greater weight. Thus, bats with prior art endcaps result in bats which are end loaded or end heavy; meaning that the weight of the barrel 4 is not uniformly distributed over the barrel length 10.

**[0054]** End caps of the invention may weigh less than 0.3 ounces (70% less than prior art plastic endcaps) for youth and softball bats and less than 0.4 ounces (70% less than prior art plastic endcaps) for adult baseball bats. Typically, the thin film high strength adhesive employed to permanently bond the polymer composite endcap 14 to the bat barrel 11 adds a weight of less than 0.1 ounces for youth and softball bats and 0.1 ounces for adult baseball bats. Thus, the total weight added to the barrel end 19 with the bonded endcap 14 of the present invention is 85% and 83% less than the prior art bonded endcaps for youth and softball, and adult baseball bats, respectively.

[0055] A typical adult baseball bat having 34 inches in length has a total weight of 31 ounces or 0.9 ounces per inch of length. A typical endcap 14 of the present invention is 0.625 inches in length 21, adhesively bonded along the segment 20 to the barrel end, and adds approximately 0.5 ounces ounces per inch of length. Thus, unlike the prior art endcaps, the light-weight composite endcap 14 of the present invention does not substantially change the weight distribution of the tubular baseball bat.

[0056] A typical adult baseball bat having 34" in length with a regulated total weight of 31 ounces, (the weight including a prior art endcap with added urethane, the endcap and urethane weighing 3.5 ounces), has a measured center gravity of 20 inches from the handle end and a measured moment of inertia of 8076 ounces-in<sup>2</sup>. Removing the prior art endcap and urethane, and replacing these with a light-weight polymer composite endcap 14 of the present invention, results in a measured center of gravity of 18.9 inches from the handle (i.e. 1.1 inch further from the barrel end 8) and a moment of inertia of 6401 ounces-in<sup>2</sup> (i.e. 21% reduction).

[0057] The changed tubular bat weight distribution resulting from the light weight polymer composite endcap 14 of the present invention is useful in redesigning existing tubular baseball bats whose performances do not meet accepted standards and in designing new tubular baseball bats to meet existing standards. Generally, both a center of gravity closer to the handle end 7 and a lower moment of inertia, lower bat performances.

[0058] Further, the changed tubular bat weight distribution resulting from the light-weight polymer composite endcap 14 of the present invention allows the player to increase the bat swing speed and improve bat control while swinging. Firstly, it is well known that a light bat can be swung faster. Secondly, hitters can control a lighter bat more effectively during the swing phase. Bat control affects the path of the bat as it crosses home plate. Increased bat control can improve batting average.

[0059] Further, the light-weight polymer composite endcap 14 of the present invention allows total tubular bat weight to be reduced by at least 1 ounce. This is particularly important in youth baseball and women's fastpitch softball, both of which

have no minimum weight limits, and whose players or hitters perform better with lower weight bats. These results are achieved according to the invention by forming the endcap of a polymer composite.

[0060] A polymer composite is a non-homogenous material consisting of fibers embedded in, and wetted by, a polymeric resin matrix whereby the properties of the polymer composite are superior to those of its constituent fibers and resin taken separately. Such polymer composites are anisotropic materials since they exhibit different responses to stresses applied in different directions depending on how the fibers are aligned or angled within the matrix. Other materials commonly used in prior art endcaps, such as aluminum and plastics, are not anisotropic. Polymer composite materials based on fibers such as carbon or graphite are approximately twenty times stiffer than plastics and four times stiffer than aluminum. This increased stiffness permits endcaps to be provided which are lighter in weight.

[0061] The significant weight reductions achieved by endcaps of the present invention are due to the inventive utilization of a polymer composite material, and are improved by a simplified geometry having a thin and substantially continuous wall thickness, and a thin film adhesive with a substantially reduced bonding area. The simple geometry polymer composite endcaps 14 of the present invention are of unitary construction, simple shape (no spokes, lugs, grooves, etc.), and have a relatively thin and substantially constant wall thickness 15. The simple geometry of the design results in low tooling costs and low manufacturing costs. The wall thickness 15 of the polymer composite endcaps 14 are typically in the order of 0.040 - 0.080 inches compared to prior art plastic endcaps which have at least twice the thickness of endcaps 14 of the present invention.

## CONCLUSION

[0061] The foregoing has constituted a description of specific embodiments showing how the invention may be applied and put into use. These embodiments are only exemplary. The invention in its broadest, and more specific aspects, is further described and defined in the claims which now follow.

[0061] These claims, and the language used therein, are to be understood in terms of the variants of the invention which have been described. They are not to be restricted to such variants, but are to be read as covering the full scope of the invention as is implicit within the invention and the disclosure that has been provided herein.

[0062] The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.